

# **MODELING OF ASSIMILATION AND TRANSPIRATION IN SOYBEAN PLANTS USING ARTIFICIAL NEURAL NETWORKS\***

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## **INTRODUCTION**

As part of the objectives for NASA's Advanced Life Support program, future bioregenerative life support systems providing a significant degree of self-sufficiency to crews for productive research and exploration of space will rely on plants to perform several functions. Through the process of photosynthesis or assimilation, plants remove carbon dioxide from the atmosphere and produce oxygen while incorporating carbon into biomass (food). Fresh water is released via the process of transpiration. Understanding and optimally controlling the dynamic functions associated with assimilation, transpiration, biomass accumulation and allocation, as well as the demands for resources (resources recovered from wastes) is essential to achieving safe and efficient support of crews during long-term space exploration or habitation.

In pursuit of these objectives, we are developing an artificial neural network control system to manage, control, and optimize plant-based life support functions. This will allow efficient growth of crop plants to provide the maximum amount of life essentials of air, water, and food to a human crew using the minimal amount of resources. Before developing the control system, neural network models characterizing plant growth functions which will be able to better interpolate between various environmental conditions and parameters and be able to simulate short-term (less than a day) and long-term (plant life cycle) responses and performance of various plants are currently being implemented. These models will provide a system identification and an understanding of plant behavior to develop the neural network control system.

## **RESEARCH**

Assimilation and transpiration are complex, nonlinear, dynamic, and multivariable plant processes where not all relationships between various environmental conditions and input sensor parameters are well defined. Artificial neural networks with their ability to learn and approximate arbitrary nonlinear input-output relationships from a collection of examples are very suitable for characterizing these plant-based life support processes. A 2-layer feedforward neural network architecture has been developed to model transpiration and assimilation for soybean crops under various environmental conditions. The inputs to the neural network model are the crop type, stage of growth, and the environmental conditions: carbon dioxide level, light intensity, air temperature. The model predicts within a limited range the amount of water (transpiration rate) and net photosynthesis (assimilation rate) produced under these conditions.

The neural network was trained by a modified error-backpropagation learning algorithm from experimental crop data. In collaboration with Rutgers University (NJ-NSCORT), controlled environment soybean crop experiments were conducted in their specially designed and constructed plant growth chamber, capable of monitoring canopy net photosynthetic rates, night respiration, and water vapor flux. Short term tests, lasting 48 hours, consisting of a factorial combination of two atmospheric carbon dioxide concentration levels (400 and 1000 ppm), three irradiances (450 and 153  $\mu\text{mol}/\text{m}^2/\text{s}$  and no light), and three air temperatures (22, 26, and 30 °C) were conducted to measure the crop responses at different environmental conditions. Although the neural network soybean model, trained on this data, can interpolate between these environmental conditions and predict the assimilation and transpiration rates, it is still limited to within these ranges. However, as more crop experiments are conducted, the neural network model can easily be expanded and refined by further training. This soybean model demonstrates how neural networks can model the complex plant processes of assimilation and transpiration.

## **INDEX TERMS**

artificial neural networks, bioregenerative life support, modeling, control, soybean, assimilation, transpiration, food, biomass, plants

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